Effects of Water State of Soil on Ecological Boundary of Leaf Surface of *Populus davidiana*[1]

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Abstract The effect of water state of soil on eco-boundary over leaf surface was disscussed by taking *Populus davidiana* as experimental material. The results show that to change soil water state by some methods was to adjust and control the forming quality of eco-boundary in fact. The plant in good water condition must be accompanied by thinner eco-boundary. This eco-boundary is beneficial to exchange and flow of the substances between plant and environment.

Key words: *Populus davidiana*, Leaf blade, Soil water, Eco-boundary

Introduction

The water state of soil as an important index for plant management restricted directly plant productivity.[1-3] Many reports discussed the process of the water absorbed by roots and transported to air by leaf. An Ohm's law analogy was frequently used to discuss water relation between the plant and the environment.[4-9] The water state of soil can be reflected by the leaf water state,[10-13] but few reports were found on evaluation of soil water by ecological boundary of leaf surface's.[14] The eco-boundary on leaf surface is a thinner air-layer which contacts closely with the leaf surface. This concept was summarized by Prof. Xiong Wenyu in 1986.[15] The eco-boundary which was forced by the environment were selected and adjusted by physiological activities of plant[16]. The water motion in the eco-boundary was determined by the united actions of environment and plant. Since the soil water influences physiological function of plant, the forming quality of eco-boundary can be controlled by changing water state of soil.

Materials

3-year-old *Populus davidiana* was used as experimental materials. Under culture condition, some of them were in obvious water stress and some were not. The intensity of water stress was expressed by soil water content (SWC)[17].

Methods

Owing to stomata of leaf surface of *Populus davidiana* completely distribute over abaxial surface, the eco-boundary we deal with are limited to the abaxial surface. We measured the moisture concentration gradients on the abaxial surface at fixed position during photosynthesis. The distribution of moisture concentration was shown in Fig.1.

In Fig.1, the abscissa expresses the moisture sampling distance which is vertical to the leaf surface, and the ordinate expresses the moisture concentration corresponding to any sampling position. The unit of the abscissa is millimeter and of the ordinate is mV (output voltage of micro-environmental humidity instrument). The parameter δ expresses the thickness of eco-boundary, which can be definited by moisture concentration gradients. Its unit is millimeter.

Obviously, the forming quality of eco-boundary can be expressed by the parameters δ and moisture concentration gradient($\Delta C=C_{leaf}-C_{air}$). When the eco-boundary is thinner and the moisture concentra-

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tion gradient is greater, the leaf loses much more water by transpiration during photosynthesis. This indicates the eco-boundary has higher penetration. The eco-boundary benefits exchange and flow of substance between plant and environment and vice versa.

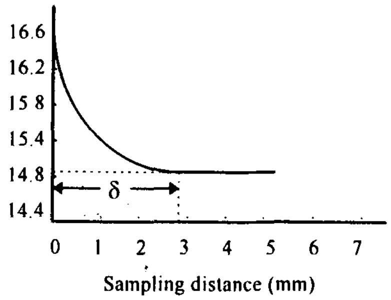

Fig.1. Moisture concentration gradients in the eco-boundary

Of course, the forming quality of eco-boundary can be calculated by informational entropy of the eco-boundary structure. Now, we can consider the moisture distribution in the eco-boundary as a real physical field, then the field's informational entropy satisfies the formula[18-19].

$$H = -\int_{v} \frac{1}{v}\bullet\left|\frac{dv}{dx}\right|\bullet\ln\left|\frac{1}{v}\bullet\frac{dv}{dx}\right|dx \qquad (1)$$

For one dimension, if we use the regressive equation

$$y = ba^{x} \qquad 0 < a < 1 \qquad (2)$$

to express the distribution of moisture concentration in the Fig.1, the eco-boundary's informational quantity would be

$$H = -\ln\left[\frac{|\ln a|}{e\bullet(a^{-\delta}-1)}\right] - \frac{\delta a^{-\delta}|\ln a|}{a^{-\delta}-1} \text{ (nat)} \qquad (3)$$

By the formula (3), one can see that the informational quantity is decided completely by parameters δ and a. The informational quantity reflects united actions of environment and organisms to the eco-boundary. When water state of soil changes, it will influence the forming quality of eco-boundary. By measuring δ and a and calculating information quantity H, we can evaluate the forming quality of eco-boundary and determine the water state of soil.

In the experiment we used the micro-environmental humidity instrument to measure the moisture concentration in eco-boundary. We used an adsorbent to adsorb the moisture in the boundary. The adsorbent was a mixture solution by acetic acid potassium and acetic acid sodium. The adsorbent was laid on platinum probe of the instrument, then a drop about 0.3 μL was formed. When the drop adsorbs moisture, its conductance will change. When moisture increase in the eco-boundary, the conductance of adsorbent solution decrease and output value(mV) of the instrument rise. The instrument we used can measure humidity from 40% to 100%, and the sampling precision is 1 mm.

Results and Analyses

The experimental results were shown in Table 1. We measured the averaged opening area of stomatal by ESM.

Table 1. The relation between the soil water and the eco-boundary

Samples	Soil water content (%)	Measure time	Stomatal opening area (μm)	Eco-boundary thickness (mm)	Parameter a	H (nat)
Wate stress	5.0 ~ 6.0	6:00 a.m.	1.0	7.0	0.973641	1.95
		10:00 a.m.	0.8	4.2	0.991783	1.43
		14:00 p.m.	0.2	5.8	0.980884	1.51
Water sufficient	11.0 ~ 13.0	6:00 a.m.	0.7	16.2	0.972531	2.78
		10:00 a.m.	11.6	4.0	0.992614	1.38
		14:00 p.m.	10.3	4.6	0.986340	1.53

At early morning, the opening area of stomatal for the plants on which the water stress does not occurr is smaller(about 0.7 μm^2) becouse of low sun light radiation, great humidity. The moisture concentration gradient is smaller and the eco-boundary is thicker about 16.2 mm. The informational quantity is 2.78 nat. For the plants that have obvious water stress, the opening area of stomatal is bigger, the eco-boundary is thinner, and the boundary informational quantity is about 1.96 nat.

At 10:00 a.m., as the sunlight radiation and temperature increasing and humidity decreasing, the stomatal opening is the biggest for the plants with sufficient soil water. The moisture concentration

gradient is the greatest also, and its boundary is the thinnest (about 4.0 mm) in daily change. This thinner boundary has a small resistance to water flow from leaf to air and has greater penetration. But, the stomatal opening is smaller for the plants with water stress, and its eco-boundary is also thicker.

About 2:00 p.m., the sunlight tradiation and the environment temperature reach the highest value, and the humidity is the lowest. The stomatal opening is still bigger for the plants with sufficient soil water and its boundary is thinner with greater penetration though the plants is in rest. But, for the plants with obvious water stress, its stomatal opening is almostly close. The moisture concentration are decided by the cutile evaporation and diffusion, so the moisture concentration gradient is smaller, the eco-boundary thicker, and the boundary resistance is greater.

Conclusions

The soil water states has close interrelation with the ecological boundary on the leaf. We can change the soil water states by some mesures to control and adjust the eco-boundary forming quality. The water states will control and adjust the substances exchange between plant and environment. The more sufficient water the soil has, the better the forming quality of eco-boundary is on leaf. This situation benefits the exchange and flow of substances between plant and environment.

References

1. Nambiar, E.K.S. 1990. Interplay between nutrients, water, root growth and productivity in young plantations. For. Ecol. Manage. 30:213-232.

2. McMurtrie, R.E., Rook, D.A. and Kelliher, F.M. 1990. Modeling the yield of *Pinus radiata* on a site limited by water and nitrogen. For. Ecol. Manage. 30: 381-413.

3. Landsberg, J.J. 1986. Physiological Ecology of Forest Production. Academic Press, London.

4. Landsberg, J.J. 1978. Water movement through plant roots. Ann. Bot. 42:493-508.

5. Newman, E.I. 1969. Resistance to water flow in soil and plant. II.A review of experimental evidence on the rhizosphere resistance. J. Appl. Ecol. 6:261-272.

6. Jarvis, P.G. 1975. Water transferinplants. In Heatand-Mass Transfer in the Plant Environment. Part I. Eds. D.A. deVries and N.G. Afgan. Scripta Book Co., Washington D.C.

7. Baldocchi, D.D. 1989a. Canopy-atmosphere water vapour exchange: cna we scalefroma leaf to a canopy? In Estimation of Areal Evapotranspiration. IAHS Pub. No. 177, pp 21-41.

8. Tyree, M.T. 1988. A dynamic model for water flow in a single tree: evidence that models must account for hydraulic architecture. Tree Physiol. 4:195-217.

9. Whitehead, D., Jarvisand, P.G., Waring, R.H. 1984b. Stomatal conductance, transpiration and resistance to water uptake in a Pinus sylvestris spacing experiment. Can. J. For. Res. 14:692-700.

10. 潘建平、韩士杰. 1995. 山杨叶片相对水分含量的日变化. 东北林业大学学报. 23(1):15-19.

11. Hsiao, T.C. 1973. Plant responses to water stress. Ann. Rev. Plant Physiol. 24:519-570.

12. Epron, D., and Dreyer, E. 1993. Photosynthesis of oak leaves under water stress: maintenance of high photo chemical efficiency of photosystem II and occurrence of non-uniform CO_2 as simulation. Tree Physiology. 13:107-117.

13. Meyer, W.S. and Reicosky, D.C. 1985. Enclosing leaves for water potential measurement and its effect on interpreting soil-induced water stress. Agri. For. Meteo. 35:187-192.

14. 韩士杰. 1996. 叶面界面生态学. 东北林业大学出版社.

15. 熊文愈等. 1986. 论生态界面系统. 南京林学院学报. (2):1-10.

16. Han Shijie et al. 1995. The boundary laye ecology - anew and developing branch of ecology. J. Northeast Forestry University(English Edition). 6(3):122-126.

17. 李吉跃等. 1997. 侧柏种源耐旱特性及其机理研究. 林业科学. 33(1):1-13.

18. 张学文. 1988. 物理场的熵及其自发减小现象. 自然杂志. 11月号:847-850.

19. 张学文. 1988. 熵与交叉学科:熵究竟是什么. 气象出版社.

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